RESEARCH DEPARTMENT

See Addendum of 8.3.66 attached to front cover.

The performance of vertical aperture correctors using a single line-period delay

RESEARCH REPORT No. T-145

1965/12

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

ADDENDUM

RESEARCH DEPARTMENT - BRITISH BROADCASTING CORPORATION

Research Report No. T-145 (1965/12)

THE PERFORMANCE OF VERTICAL APERTURE CORRECTORS
USING A SINGLE LINE-PERIOD DELAY

Improved Circuit

Research Report No. T-145 described a vertical aperture corrector which used recirculation to allow for the use of only one line-period delay. Fig. 4 of that report showed a practical form of this corrector in which there existed at one point (marked X) a correcting signal which was absent in plain areas. This correcting signal could be adjusted in level by means of an attenuator, or processed in other ways, without affecting the picture in plain areas. One disadvantage of this vertical aperture corrector* is the fact that if a filter is used in the path of the correcting signal - for example to reduce noise, or to avoid tampering with the chrominance signal - it is not possible to correct for the delay inherent in the filter. The purpose of this Addendum is to propose a rearranged circuit which does permit compensation for delay introduced into the path of the correcting signal.

The improved circuit is shown in Fig. A. It is assumed that the correcting signal is passed through a low-pass filter or other means of processing having a time delay T. In order to compensate for this delay T the principal delay is reduced from L, the line period, to L-T. Additional delays equal to T are introduced at the input and output of the main delay as shown in the figure. The delay of the main signal is now L+T instead of L as formerly. All the components of the correcting signal are now correctly timed with respect to the main signal.

* Pointed out by Mr. W. Wharton.

CHD
8.3.66.

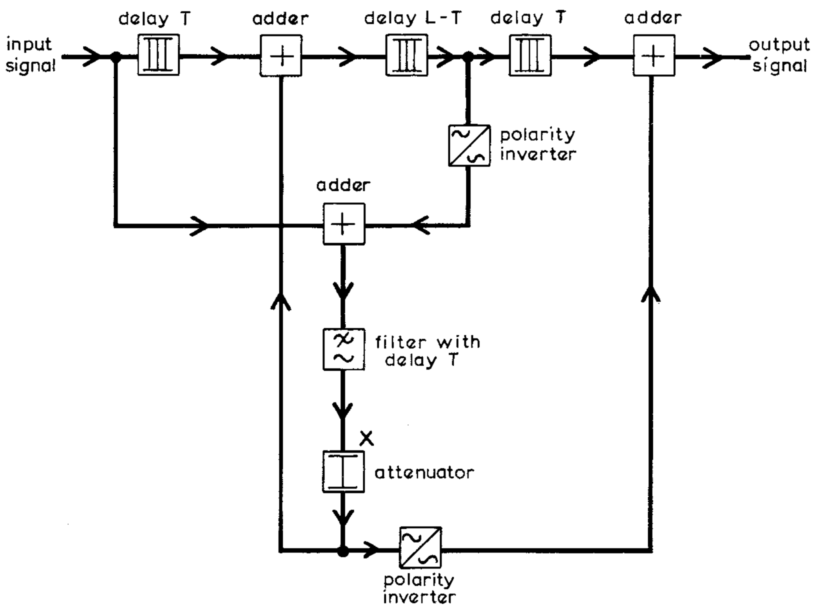
delay T
adder
delay L-T
delay T
adder
input signal
output signal
polarity inverter
adder
filter with delay T
X
attenuator
polarity inverter

Fig. A

RESEARCH DEPARTMENT

THE PERFORMANCE OF VERTICAL APERTURE CORRECTORS USING A SINGLE LINE-PERIOD DELAY

Research Report No. T-145

(1965/12)

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Research Report No. T-145

THE PERFORMANCE OF VERTICAL APERTURE CORRECTORS USING A SINGLE LINE-PERIOD DELAY

May 1965 Research Report No. T-145

(1965/12)

THE PERFORMANCE OF VERTICAL APERTURE CORRECTORS USING A SINGLE LINE-PERIOD DELAY

SUMMARY

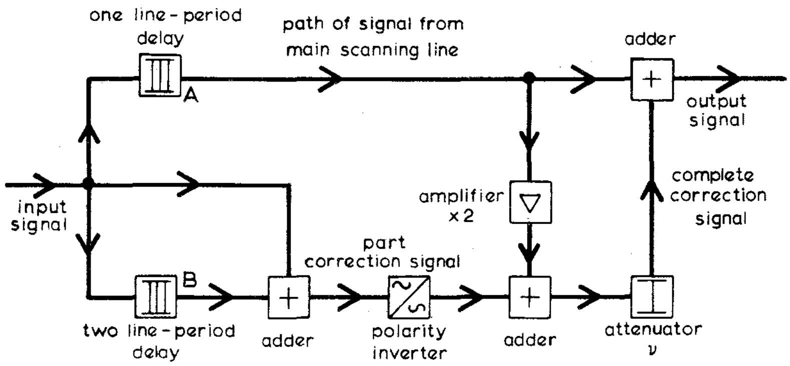
Vertical aperture correction of a television picture can be achieved by deducting, from the signal corresponding to each scanning line, signals corresponding to the preceding and succeeding scanning lines in the same field. Hitherto, in order to perform this process, two line-period delays* have been required. In this report, however, tests are described which were made in order to assess the feasibility of vertical aperture correction using a single line-period delay. Two possible forms of vertical aperture corrector are described and their subjective performances are compared with that of a corrector using two delays.

1. INTRODUCTION

In recent years, vertical aperture correction[1] of a television signal has become possible due to the development of wide-band ultrasonic delays.[2] A practical method of vertical aperture correction was first proposed by W.G. Gibson and A.C. Schroeder of R.C.A.[1] and involved a deduction, from the signal of each scanning line (which for convenience will be called the main scanning line), of information from the preceding and succeeding scanning lines in the same field. The method compensates for the loss of vertical resolution which occurs in television cameras and scanners and has been found in practice to give a significant improvement in the subjective quality of television pictures. A vertical aperture corrector of this type is shown in Fig. 1.

The fact that information from three successive scanning lines in the same field is required simultaneously necessitates the use of two delays. It has, however, been suggested that a worthwhile reduction in cost and complexity would result if a vertical aperture corrector could be designed which employed only a single line-period delay. Two possible forms of vertical aperture corrector requiring only a single line-period delay have, in fact, been proposed and their performance is discussed in this report.

* To avoid confusion with a television scanning line, a delay line is referred to simply as a delay.



Let the sequence of signals from input scanning lines be e_{n-2}, e_{n-1}, e_n ..... Then the sequence of signals at A is e_{n-3}, e_{n-2}, e_{n-1}, e_n ..... and the sequence of signals at B is e_{n-4}, e_{n-3}, e_{n-2}, e_{n-1}, e_n ..... If e_{n-1} is the signal from the main scanning line, then the output signal is $e_{n-1} + \nu(2\, e_{n-1} - e_n - e_{n-2})$ where ν is the relative amplitude of the correction signal.

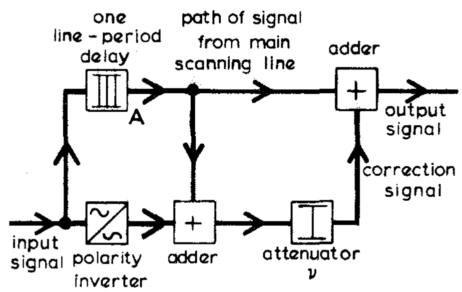
Fig. 1 - Block schematic of vertical aperture corrector using two delays

2. VERTICAL APERTURE CORRECTORS USING A SINGLE LINE-PERIOD DELAY

2.1. The Asymmetric Vertical Aperture Corrector

It had been suggested that a vertical aperture corrector could be made using only one line-period delay and deriving the correcting signal from either the line preceding or the line succeeding the main scanning line. In the arrangement shown in Fig. 2, the correction signal is derived from the succeeding scanning line. Vertical aperture correction will thus be asymmetric.

It should be noted that the circuit of Fig. 2 is so arranged that the correction signal comprises signals derived from both the main scanning line and the adjacent scanning line. Thus, if there is no vertical information in the picture, the correction signal has zero magnitude; the mean brightness of the corrected picture is therefore independent of the amplitude of the correction signal.



Let the sequence of signals from input scanning lines be e_{n-2}, e_{n-1}, e_n ..... Then the sequence of signals at A is e_{n-3}, e_{n-2}, e_{n-1}, e_n ..... If e_{n-1} is the signal from the main scanning line, then the output signal is $e_{n-1} + \nu(e_{n-1} - e_n)$ where ν is the relative amplitude of the correction signal.

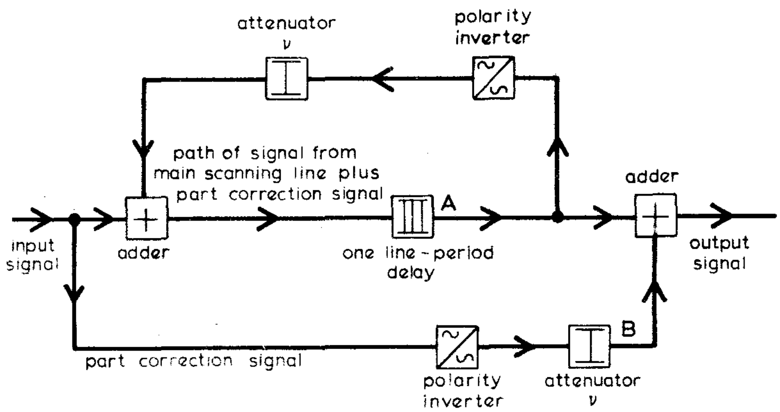
Fig. 2 - Block schematic of asymmetric vertical aperture corrector

2.2. The Re-Circulating Vertical Aperture Corrector

A block schematic of this form of vertical aperture corrector* is shown in Fig. 3 and it is supposed that a sequence of scanning lines, whose signals may be denoted e_1 e_2 ..... e_n, is applied to the input. The signal corresponding to the main scanning line is derived from the output of the one

* The re-circulating form of vertical aperture corrector shown in Figs. 3 and 4 was suggested by Mr. G.D. Monteath of BBC Research Department.

line-period delay and it is convenient to assume that this is the signal e_{n-1}. The correction signal is derived from the signal e_n (which is undelayed) and the signal e_{n-2}, which is obtained by re-circulation through the delay. In addition to the signal e_{n-2}, the re-circulation introduces unwanted signals e_{n-3}, e_{n-4}, e_{n-5} ....., having descending magnitudes, from previous lines and the effect of these unwanted signals is to produce 'ringing' on the lower edges of diagonal and horizontal transitions in the picture. The ringing will, of course, increase in magnitude as the amount of vertical aperture correction is increased and the arrangement would, therefore, be unsatisfactory if very large amounts of correction were required.

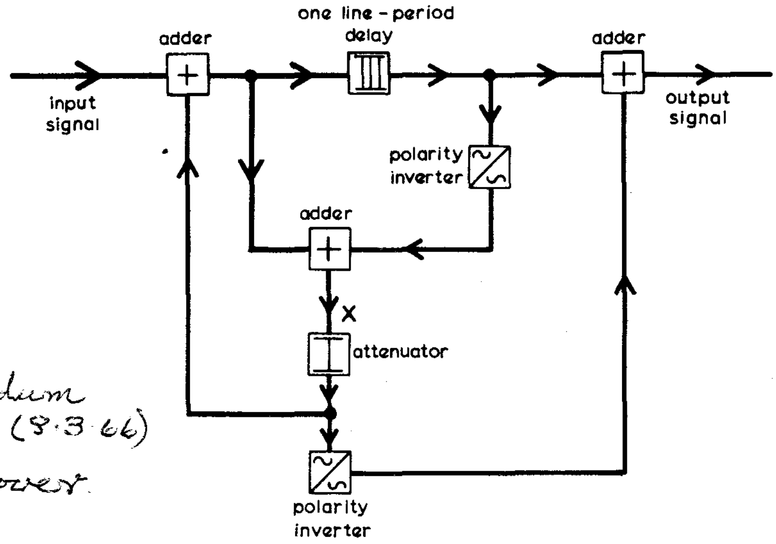


Let the sequence of signals from input scanning lines be e_{n-4}, e_{n-3}, e_{n-2}, e_{n-1}, e_n ..... When the signal from the input line is e_n, the main scanning line is e_{n-1} and the total signal at A is $e_{n-1} - \nu\, e_{n-2} + \alpha(t)$ where $\alpha(t) = + \nu^2\, e_{n-3} - \nu^3\, e_{n-4} + \ldots$ The signal at B is $-\nu\, e_n$ so that the total output signal is $e_{n-1} - \nu(e_n + e_{n-2}) + \alpha(t)$.

Fig. 3 - Block schematic of re-circulating vertical aperture corrector

In the arrangement shown in Fig. 3, it will be seen that no component of the signal from the main scanning line is added to the correction signal. Thus, if there is no vertical information in the picture, the amplitude of the correction signal is not zero and the mean brightness of the corrected picture varies with the amount of vertical aperture correction applied. This disadvantage is overcome by the circuit shown in Fig. 4, in which a subtractor forms the difference between the signals at the input and output of the delay. This difference is then subtracted from the output of the delay and added to the input. This circuit has precisely the same effect as the circuit of Fig. 3 when both circuits are correctly adjusted, but is much easier to adjust, since variation of the attenuator, which determines the degree of correction, has no effect on the mean brightness of the picture.

A further advantage of the circuit of Fig. 4 is that a network may be inserted at the point marked 'X' so as to modify the correction, without in any way modifying the picture where there is no vertical detail. Thus it might prove advantageous to insert a low-pass filter or band-stop filter at X so as to avoid modifying the chrominance signal when applying the correction to colour signals. Alternatively a non-linear network designed to suppress weak signals could be placed at X to avoid noise in plain areas being accentuated by the correction. Such an arrangement, analogous to 'crispening' (crispening affects only horizontal detail) was proposed by



See addendum attached (8·3·66) to front cover.

Fig. 4 - Block schematic of improved re-circulating vertical aperture corrector

Newell for a vertical aperture corrector using two delays, such as that shown in Fig. 1, and is being described in another report.[3] It is not applicable to the circuit of Fig. 3.

3. SUBJECTIVE MEASUREMENTS

The object of these measurements was to compare, subjectively, the results of vertical aperture correction obtained using the methods employing a single one-line period delay with that employing two delays. It should be pointed out that the use of vertical aperture correction, whilst improving the vertical resolution of a picture, results in a reduction of the signal-to-noise ratio and for this reason, two series of experiments were carried out:

(a) Using a flying-spot slide scanner which provided a picture source with a high signal-to-noise ratio (45 dB). With this arrangement the added noise due to vertical aperture correction had no significant effect on the results.

(b) Using a film scanner which provided moving pictures typical of both good and bad programme material. With this arrangement, the added noise due to vertical aperture correction affected the results but it was possible to assess the maximum amount of vertical aperture correction likely to be required under practical conditions.

3.1. Measurements Made Using Flying-Spot Scanner

A group of five technical observers was used who were asked to compare the pictures obtained, after the various types of vertical aperture correction had been applied, with uncorrected pictures. The observers were asked to grade the comparisons using the scale shown in Table 1.

TABLE 1

Comparison Scale Used for Subjective Measurements

+3	Much better
+2	Better
+1	Slightly better
0	Same as
-1	Slightly worse
-2	Worse
-3	Much worse

The experimental arrangement used in the tests is shown in Fig. 5 and it will be seen that the pictures with vertical aperture correction were derived from:

(a) A conventional aperture corrector employing two delays,[2] Fig. 1.

(b) The re-circulating vertical aperture corrector, Fig. 3.

(c) The asymmetric vertical aperture corrector, Fig. 2.

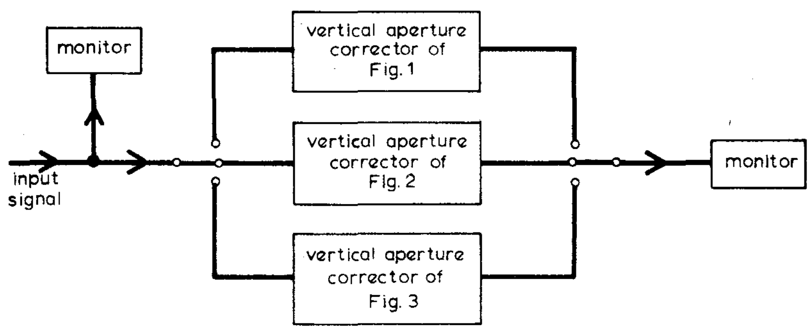


Fig. 5 - Block schematic of experimental arrangement for the tests

The first was included so that direct comparisons could be made between the subjective improvements obtained with a conventional vertical aperture corrector and with vertical aperture correctors using a single line-period delay.

The observers were asked to compare the corrected and uncorrected pictures, in terms of picture sharpness and overall picture quality, for values of the calibration factor of 0, 0·1, 0·167 and 0·25.* In all cases, the picture on which the comparisons were made was Test Card 'C'.

* If the signals corresponding to the main scanning line and the preceding and succeeding scanning lines are denoted by e_2, e_1 and e_3 respectively, the corrected signal may be written:[2]

$e_2 - \xi(e_1 + e_3)$ where ξ has been termed the calibration factor. In the case of the asymmetric vertical aperture corrector, the calibration factor ξ was defined so that the corrected signal was: $e_2 - \xi e_1$ or $e_2 - \xi e_3$.

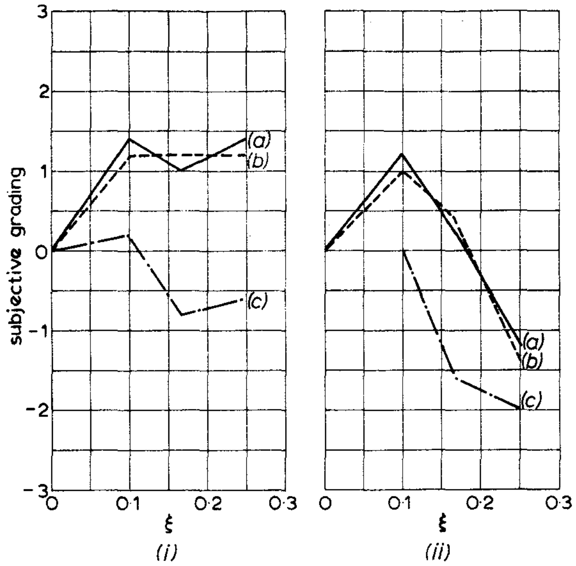


Fig. 6 - Subjective effect of vertical aperture correction on Test Card 'C'

Input signal-to-noise level = 45 dB

A positive value indicates that vertical aperture correction produced a subjective improvement

(*i*) Picture sharpness (*ii*) Overall picture quality

(*a*) Vertical aperture corrector using two one line-period delays
(*b*) Re-circulating vertical aperture corrector (*c*) Asymmetric vertical aperture corrector

The results obtained from the subjective comparisons are shown in the form of graphs in Fig. 6, each point on the graph being the average of the opinions of the five observers. Fig. 6(i) shows comparisons between the corrected and uncorrected picture in terms of picture sharpness, whilst in Fig. 6(ii) the criterion was overall picture quality. Figs. 6(i) and 6(ii) each consist of three curves corresponding to:

(a) The conventional vertical aperture corrector using two delays, Fig. 1.

(b) The re-circulating vertical aperture corrector, Fig. 3.

(c) The asymmetric vertical aperture corrector, Fig. 2.

It will be seen from Fig. 6 that the curves corresponding to the asymmetric vertical aperture corrector compare unfavourably with the results obtained for the other forms of vertical aperture correction and, for larger values of the calibration factor, it was considered by the observers to reduce the sharpness and overall quality of the input picture signal.

The curves corresponding to the re-circulating vertical aperture corrector were almost identical with those for the vertical aperture corrector employing two

delays, both for picture sharpness, Fig. 6(i), and for overall picture quality, Fig. 6(ii). With both of these two forms of vertical aperture corrector, the observers considered that picture sharpness was improved for all values of the calibration factor but that overall picture quality, whilst being improved for small values of calibration factor was degraded when the value became large.

3.2. Measurements Made with Film Scanner

The Test Card 'C' used in the subjective measurements discussed in Section 3.1 was obtained from a flying-spot slide scanner and the picture thus had good vertical resolution. The amount of improvement obtainable by the use of vertical aperture correction was therefore limited. Pictures of poorer quality, such as those derived from television film recording, may require larger amounts of vertical aperture correction. Under these circumstances, it is possible that the amount of correction required may be such that the 'ringing' produced by the re-circulating vertical aperture corrector (as described in Section 2.2) would become subjectively annoying before the optimum amount of correction had been applied. For this reason some further comparisons were made between the re-circulating and conventional aperture correctors using moving pictures of a quality that might be met with in practice. Since the tests described in Section 3.1 had shown that the asymmetric corrector gave no improvement in picture quality only the conventional and re-circulating types of corrector were used. For the tests, four sequences of moving pictures were used; two sequences were of poor quality television film recording and two were of good quality optical film. The technical observers, in turn, were shown the four film sequences and for each sequence were asked to adjust both the re-circulating and the conventional vertical aperture correctors for optimum improvement in picture quality. The results are shown in Table 2, each figure being the mean of the settings derived by the observers. To determine the maximum amount of correction obtainable with the re-circulating vertical aperture corrector, the magnitude of the correcting signal was adjusted using Test Card 'C' until the ringing just became visible; this was found to occur for a calibration factor of 0·18.

TABLE 2

FILM SEQUENCE	CALIBRATION FACTOR (ξ)	
	RE-CIRCULATING VERTICAL APERTURE CORRECTOR	CONVENTIONAL VERTICAL APERTURE CORRECTOR
Good optical film	0·15	0·18
Good optical film	0·16	0·17
Poor film recording	0·15	0·2
Poor film recording	0·16	0·18

From the results in Table 2 it can be seen that there is a slight tendency for the observers to choose a lower value of calibration factor when using the re-circulating vertical aperture corrector than when using the conventional type of corrector.

However, none of the values of calibration factor used to correct the film sequences exceeded that value at which ringing became apparent on Test Card 'C'. It would therefore appear that the small difference between the two values of calibration factor cannot be significant and that under practical conditions the re-circulating vertical aperture corrector is a satisfactory substitute for the conventional corrector.

4. CONCLUSIONS

In this report two forms of vertical aperture corrector employing a single line-period delay have been investigated and their performances have been compared with that of a conventional vertical aperture corrector using two delays. The results of the tests made show that though the asymmetric vertical aperture corrector has an inferior performance, the use of the re-circulating vertical aperture corrector results in pictures which are subjectively identical with those produced by a conventional vertical aperture corrector employing two delays.

5. REFERENCES

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2. 'Vertical Aperture Correction using Continuously-Variable Ultrasonic Delay Lines', BBC Engineering Division Monograph No. 47, May 1963.

3. 'Vertical Aperture Correction with Minimal Increase in Noise', Research Department report in preparation.

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